SECTION 15951A

DIRECT DIGITAL CONTROL FOR HVAC
06/98

PART 1   GENERAL

1.1   REFERENCES

The publications listed below form a part of this specification to the
extent referenced. The publications are referred to in the text by basic
designation only.

           AIR MOVEMENT AND CONTROL ASSOCIATION (AMCA)

AMCA 500   (11989; Rev994) Test Methods for Louvers,
                                 Dampers and Shutters

           AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1   (1995) Code for Electricity Metering

           AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A 269   (1996) Seamless and Welded Austenitic
                                 Stainless Steel Tubing for General Service

ASTM B 88   (1996) Seamless Copper Water Tube

ASTM B 88M   (1996) Seamless Copper Water Tube (Metric)

ASTM D 635   (1997) Rate of Burning and/or Extent and
                                 Time of Burning of Self-Supporting Plastics
                                 in a Horizontal Position

ASTM D 1693   (1997a) Environmental Stress-Cracking of
                                 Ethylene Plastics

           AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
           ENGINEERS (ASHRAE)

           ASME INTERNATIONAL (ASME)

ASME B16.34   (199; B16.34a) Valves - Flanged, Threaded,
                                 and Welding End

ASME B40.1   (1991) Gauges - Pressure Indicating Dial
                                 Type - Elastic Element

ASME BPV VIII Div 1   (1998) Boiler and Pressure Vessel Code;
                                 Section VIII, Pressure Vessels Division 1 -
                                 Basic Coverage

           ELECTRONIC INDUSTRIES ALLIANCE (EIA)

| EIA ANSI/EIA/TIA 232-F | (1991) Interface Between Data Technical Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange |

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

| IEEE C62.41 | (1991; R 1995) Surge Voltages in Low-Voltage AC Power Circuits |
| IEEE Std 142 | (1991) IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems |

INSTRUMENT SOCIETY OF AMERICA (ISA)

| ISA S7.0.01 | (1996) Quality Standard for Instrument Air |

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(1991) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 1	(1993) Industrial Control and Systems
NEMA ST 1	(1988) Specialty Transformers (Except General-Purpose Type)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

| NFPA 70 | (1999) National Electrical Code |
| NFPA 90A | (1996) Installation of Air Conditioning and Ventilating Systems |

UNDERWRITERS LABORATORIES (UL)

UL 94	(1996; Rev thru Jul 1998) Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
UL 268A	(1998) Smoke Detectors for Duct Application
UL 508	(1993; Rev thru Oct 1997) Industrial Control Equipment
UL 555S	(1996) Leakage Rated Dampers for Use in Smoke Control Systems

1.2   GENERAL REQUIREMENTS

The direct digital control (DDC) shall be a complete system suitable for the heating, ventilating and air-conditioning (HVAC) system. The local building controls system network must be Echelon LONWORKS based on Echelon's LNS network operating system. All nodes shall communicate with each other over a twisted pair of wires, utilizing Echelon's free topology within a building. LonMaker for Windows must be used to design,

commission, operate, and maintain the multi-vendor, open, interoperable
LONWORK control network. The current upgrade version of this software will
be turned over to the Fort Hood Control Technology Shop (with full
documentation) and license as an operation and maintenance tool at the time
of commissioning. Each building shall be provided with an iLon 1000 with
full graphic programming to represent the control drawings and system as
described in the contract as an intranet and internet accessible web page
with full access to all control values and set points from the intranet or
internet via .htm or .html formats. System inter-operability coordination
is expressly made a part of the control contractor/integrator's
responsibility to assure that the major pieces of HVAC equipment, ie
chillers, boilers and variable frequency drives, the ilon is compatible to
produce a functional building to the extent that the contractual control
drawings and specifications require the interconnection.

1.2.1   Nameplates, Lens Caps, and Tags

Nameplates and lens caps bearing legends as shown and tags bearing
device-unique identifiers as shown shall have engraved or stamped
characters. A plastic or metal tag shall be mechanically attached directly
to each device or attached by a metal chain or wire.

1.2.2   Verification of Dimensions

After becoming familiar with all details of the work, the Contractor shall
verify all dimensions in the field, and shall advise the Contracting
Officer of any discrepancy before performing any work.

1.2.3   Drawings

Because of the small scale of the drawings, it is not possible to indicate
all offsets, fittings, and accessories that may be required. The
Contractor shall carefully investigate the mechanical, electrical, and
finish conditions that could affect the work to be performed, shall arrange
such work accordingly, and shall furnish all work necessary to meet such
conditions.

1.2.4   Power-Line Surge Protection

Equipment connected to ac circuits shall be protected from power-line
surges. Equipment protection shall meet the requirements of IEEE C62.41.
Fuses shall not be used for surge protection.

1.2.5   Surge Protection for Transmitter and Control Wiring

DDC system control-panel equipment shall be protected against surges
induced on control and transmitter wiring installed outside and as shown.
The equipment protection shall be tested in the normal mode and in the
common mode, using the following two waveforms:

    a. A 10-microsecond by 1,000-microsecond waveform with a peak voltage
of 1,500 volts and a peak current of 60 amperes.

    b. An eight microsecond by 20-microsecond waveform with a peak
voltage of 1,000 volts and a peak current of 500 amperes.

1.2.6   System Overall Reliability Requirement

The system shall be configured and installed to yield a mean time between failure (MTBF) of at least 40,000 hours. Each DDC controller shall be designed, configured, installed and programmed to provide for stand alone operation with minimal performance degradation on failure of other system components to which it is connected or with which it communicates.

1.2.7   DDC System Network Accessibility

Where the systems to be controlled by the DDC system are located in multiple mechanical rooms, each mechanical room shall have at least one communication port for the system laptop PC. DDC controllers shall be located in the same room as the equipment being controlled or in an adjacent space which has direct access to the equipment room. A complete fiber to copper FTR Router will be located at the network entrance to the ilon in the building. Fiber Optics will be used for network communications between all buildings.

1.2.8   System Accuracy and Display

The system shall maintain an end-to-end accuracy for one year from sensor to operator's console display for the applications specified and shall display the value as specified. Each temperature shall be displayed and printed to nearest 0.05 degree C. 0.1 degree F.

1.2.8.1   Space Temperature

Space temperature with a range of 10 to 30 degrees C 50 to 85 degrees Fplus or minus 0.5 degrees C 0.75 degree Ffor conditioned space; minus 1 to plus 55 degrees C 30 to 130 degrees Fplus or minus 0.5 degrees C 1 degree Ffor unconditioned space.

1.2.8.2   Duct Temperature

Duct temperature with a range of 5 to 60 degrees C 40 to 140 degrees Fplus or minus 1 degree C. 2 degrees F.

1.2.8.3   Outside Air Temperature

Outside air (OA) temperature with a range of minus 35 to plus 55 degrees C minus 30 to plus 130 degrees F plus or minus 1 degree C; 2 degrees F; with a subrange of minus 1 to plus 40 degrees C 30 to 100 degrees F plus or minus 0.5 degree C. 1 degree F.

1.2.8.4   Water Temperature

Water temperature with a range of minus 1 to plus 40 degrees C 30 to 100 degrees Fplus or minus 0.5 degree C; 0.75 degree F;the range of 40 to 120 degrees C 100 to 250 degrees Fplus or minus 1 degree C.

1.2.8.5   High Temperature

High temperature with a range of 100 to 260 degrees C 200 to 500 degrees F plus or minus 1 degree C. 2.0 degrees F.

1.2.8.6   Relative Humidity

Relative humidity, within a range of 20 to 80 percent, plus or minus 6.0 percent of range (display and print to nearest 1.0 percent).

1.2.8.7   Pressure

  Pressure with a range for the specific application plus or minus 2.0
  percent of range display and print to nearest kPa.

1.2.8.8   Flow

  Flow with a range for the specific application plus or minus 3.0 percent of
  range, and flows for the purpose of thermal calculations to plus or minus
  2.0 percent of actual flow (display and print to nearest unit, such as
  liters per second). gallons per minute).

1.2.8.9   Analog Value Input

  An analog value input to the system's equipment via an AI with a maximum
  error of 0.50 percent of range, not including the sensor or transmitter
  error. This accuracy shall be maintained over the specified environmental
  conditions.

1.3   SUBMITTALS

  Government approval is required for submittals with a "G" designation;
  submittals not having a "G" designation are for information only. When
  used, a designation following the "G" designation identifies the office
  that will review the submittal for the Government. The following shall be
  submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

    SD-02 Shop Drawings

        HVAC Control System; G, RE

          Drawings shall be on A1 (841 by 594 mm) 34 by 22 inchsheets in
        the form and arrangement shown. The drawings shall use the same
        abbreviations, symbols, nomenclature and identifiers shown. Each
        control system element on a drawing shall have a unique identifier
        as shown. The HVAC Control System Drawings shall be delivered
        together as a complete submittal. Deviations must be approved by
        the Contracting Officer. Drawings shall be submitted along with
        Submittal SD-03, Product Data.

          a. HVAC Control System Drawings shall include the following:

            Sheet One: Drawing Index, HVAC Control System Legend.

            Sheet Two: Valve Schedule, Damper Schedule.

            Sheet Three: Control System Schematic and Equipment Schedule.

            Sheet Four: Sequence of Operation and Data Terminal Strip
        Layout.

            Sheet Five: Control Loop Wiring Diagrams.

            Sheet Six: Motor Starter and Relay Wiring Diagram.

            Sheet Seven: Communication Network and Block Diagram.

Sheet Eight: DDC Panel Installation and Block Diagram.

(Repeat Sheets Three through Six for each HVAC System.)

   b. The HVAC Control System Drawing Index shall show the name and
number of the building, military site, State or other similar
designation, and Country. The Drawing Index shall list HVAC
Control System Drawings, including the drawing number, sheet
number, drawing title, and computer filename when used. The HVAC
Control System Legend shall show generic symbols and the name of
devices shown on the HVAC Control System Drawings.

   c. The valve schedule shall include each valve's unique
identifier, size, flow coefficient KvCv, pressure drop at specified
flow rate, spring range, actuator size, close-off pressure data,
dimensions, and access and clearance requirements data. Valve
schedules may be submitted in advance but shall be included in the
complete submittal.

   d. The damper schedule shall contain each damper's and each
actuator's identifier, nominal and actual sizes, orientation of
axis and frame, direction of blade rotation, spring ranges,
operation rate, locations of actuators and damper end switches,
arrangement of sections in multi-section dampers, and methods of
connecting dampers, actuators, and linkages. The Damper Schedule
shall include the maximum leakage rate at the operating
static-pressure differential. The Damper Schedule shall contain
actuator selection data supported by calculations of the torque
required to move and seal the dampers, access and clearance
requirements. Damper schedules may be submitted in advance but
shall be included in the complete submittal.

   e. The HVAC control system schematics shall be in the form
shown, and shall show all control and mechanical devices associated
with the HVAC system. A system schematic drawing shall be
submitted for each HVAC system.

   f. The HVAC control system equipment Schedule shall be in the
form shown. All devices shown on the drawings having unique
identifiers shall be referenced in the equipment schedule.
Information to be included in the equipment schedule shall be the
control loop, device unique identifier, device function, setpoint,
input range, and additional important parameters (i.e., output
range). An equipment schedule shall be submitted for each HVAC
system.

   g. The HVAC control system sequence of operation shall reflect
the language and format of this specification, and shall refer to
the devices by their unique identifiers as shown. No operational
deviations from specified sequences will be permitted without prior
written approval of the Contracting Officer. Sequences of
operation shall be submitted for each HVAC control system.

   h. The HVAC control system wiring diagrams shall be functional
wiring diagrams which show the interconnection of conductors and
cables to HVAC control panel terminal blocks and to the identified
terminals of devices, starters and package equipment. The wiring
diagrams shall show necessary jumpers and ground connections. The

wiring diagrams shall show the labels of all conductors. Sources of power required for HVAC control systems and for packaged equipment control systems shall be identified back to the panel board circuit breaker number, HVAC system control panel, magnetic starter, or packaged equipment control circuit. Each power supply and transformer not integral to a controller, starter, or packaged equipment shall be shown. The connected volt-ampere load and the power supply volt-ampere rating shall be shown. Wiring diagrams shall be submitted for each HVAC control system.

SD-03 Product Data

Service Organizations; G, RE

   Six copies of a list of service organizations qualified to service the HVAC control system. The list shall include the service organization name, address, technical point of contact and telephone number, and contractual point of contact and telephone number.

Equipment Compliance Booklet; G, RE

   The HVAC Control System Equipment Compliance Booklet (ECB) shall be in booklet form and indexed, with numbered tabs separating the information on each device. It shall consist of, but not be limited to, data sheets and catalog cuts which document compliance of all devices and components with the specifications. The ECB shall be indexed in alphabetical order by the unique identifiers. Devices and components which do not have unique identifiers shall follow the devices and components with unique identifiers and shall be indexed in alphabetical order according to their functional name. The ECB shall include a Bill of Materials for each HVAC Control System. The Bill of Materials shall function as the Table of Contents for the ECB and shall include the device's unique identifier, device function, manufacturer, model/part/catalog number used for ordering, and tab number where the device information is located in the ECB. The ECB shall be submitted along with Submittal SD-02, Shop Drawings.

Commissioning Procedures;

   Six copies of the HVAC control system commissioning procedures, in booklet form and indexed, 60 days prior to the scheduled start of commissioning. Commissioning procedures shall be provided for each HVAC control system, and for each type of terminal unit control system. The Commissioning procedures shall reflect the format and language of this specification, and refer to devices by their unique identifiers as shown. The Commissioning procedures shall be specific for each HVAC system, and shall give detailed step-by-step procedures for commissioning of the system.

   a. The Commissioning procedures shall include detailed, product specific set-up procedures, configuration procedures, adjustment procedures, and calibration procedures for each device. Where the detailed product specific commissioning procedures are included in manufacturer supplied manuals, reference may be made in the HVAC control system commissioning procedures to the manuals.

b. An HVAC control system commissioning procedures equipment list shall be included that lists the equipment to be used to accomplish commissioning. The list shall include manufacturer name, model number, equipment function, the date of the latest calibration, and the results of the latest calibration.

Performance Verification Test Procedures;

   Six copies of the HVAC Control System Performance Verification Test Procedures, in booklet form and indexed, 60 days before the Contractor's scheduled test dates. The performance verification test procedures shall refer to the devices by their unique identifiers as shown, shall explain, step-by-step, the actions and expected results that will demonstrate that the HVAC control system performs in accordance with the sequences of operation, and other contract documents. An HVAC control system performance verification test equipment list shall be included that lists the equipment to be used during performance verification testing. The list shall include manufacturer name, model number, equipment function, the date of the latest calibration, and the results of the latest calibration.

Training;

   An outline for the HVAC control system training course with a proposed time schedule. Approval of the planned training schedule shall be obtained from the Government at least 60 days prior to the start of the training. Six copies of HVAC control system training course material 30 days prior to the scheduled start of the training course. The training course material shall include the operation manual, maintenance and repair manual, and paper copies of overheads used in the course.

SD-06 Test Reports

   Commissioning Report;

   Six copies of the HVAC Control System Commissioning Report, in booklet form and indexed, within 30 days after completion of the system commissioning. The commissioning report shall include data collected during the HVAC control system commissioning procedures and shall follow the format of the commissioning procedures. The commissioning report shall include all configuration checksheets with final values listed for all parameters, setpoints, P, I, D setting constants, calibration data for all devices, results of adjustments, and results of testing.

   Performance Verification Test;

   Six copies of the HVAC Control System Performance Verification Test Report, in booklet form and indexed, within 30 days after completion of the test. The HVAC control system performance verification test report shall include data collected during the HVAC control system performance verification test. The original copies of all data gathered during the performance verification test shall be turned over to the Government after Government approval of the test results.

SD-10 Operation and Maintenance Data

Operation Manual;
Maintenance and Repair Manual;

Six copies of the HVAC Control System Operation Manual and HVAC Control System Maintenance and Repair Manual, for each HVAC control system, 30 days before the date scheduled for the training course.

1.4   DELIVERY AND STORAGE

Products shall be stored with protection from the weather, humidity and temperature variations, dirt and dust, and other contaminants, within the storage condition limits published by the equipment manufacturer. Dampers shall be stored so that seal integrity, blade alignment and frame alignment are maintained.

1.5   OPERATION MANUAL

An HVAC control system operation manual in indexed booklet form shall be provided for each HVAC control system. The operation manual shall include the HVAC control system sequence of operation, and procedures for the HVAC system start-up, operation and shut-down. The operation manual shall include as-built HVAC control system detail drawings. The operation manual shall include the as-built configuration checksheets, the procedures for changing HVAC control system setpoints, and the procedures for placing HVAC system controllers in the manual control mode.

a.   The procedures for changing HVAC control system setpoints shall describe the step-by-step procedures required to change the process variable setpoints, the alarm setpoints, the bias settings, and setpoint reset schedules.

b.   The procedures for placing HVAC system controllers in the manual control mode shall describe step-by-step procedures required to obtain manual control of each controlled device and to manually adjust their positions.

1.6   MAINTENANCE AND REPAIR MANUAL

An HVAC control system maintenance and repair manual in indexed booklet form in hardback binders shall be provided for each HVAC control system. The maintenance and repair manual shall include the routine maintenance checklist, a recommended repair methods list, a list of recommended maintenance and repair tools, the qualified service organization list, the as-built commissioning procedures and report, the as-built performance verification test procedures and report, and the as-built equipment data booklet.

a.   The routine maintenance checklist shall be arranged in a columnar format. The first column shall list all devices listed in the equipment compliance booklet, the second column shall state the maintenance activity or state no maintenance required, the third column shall state the frequency of the maintenance activity, and the fourth column for additional comments or reference.

b.   The recommended repair methods list shall be arranged in a

columnar format and shall list all devices in the equipment data compliance booklet and state the guidance on recommended repair methods, either field repair, factory repair, or whole-item replacement.

 c. The as-built equipment data booklet shall include the equipment compliance booklet and manufacturer supplied user manuals and information.

 d. If the operation manual and the maintenance and repair manual are provided in a common volume, they shall be clearly differentiated and separately indexed.

1.7 MAINTENANCE AND SERVICE

Services, materials and equipment shall be provided as necessary to maintain the entire system in an operational state as specified for a period of one year after successful completion and acceptance of the Performance Verification Test. Impacts on facility operations shall be minimized.

1.7.1 Description of Work

The adjustment and repair of the system shall include the manufacturer's required adjustments of computer equipment, software updates, transmission equipment and instrumentation and control devices.

1.7.2 Personnel

Service personnel shall be qualified to accomplish work promptly and satisfactorily. The Government shall be advised in writing of the name of the designated service representative, and of any changes in personnel.

1.7.3 Scheduled Inspections

Two inspections shall be performed at six-month intervals (or less if required by the manufacturer), and all work required shall be performed. Inspections shall be scheduled in June and December. These inspections shall include:

 a. Visual checks and operational tests of equipment.

 b. Fan checks and filter changes for control system equipment.

 c. Clean control system equipment including interior and exterior surfaces.

 d. Check and calibrate each field device. Check and calibrate 50 percent of the total analog points during the first inspection. Check and calibrate the remaining 50 percent of the analog points during the second major inspection. Certify analog test instrumentation accuracy to be twice that of the device being calibrated. Randomly check at least 25 percent of all digital points for proper operation during the first inspection. Randomly check at least 25 percent of the remaining digital points during the second inspection.

 e. Run system software diagnostics and correct diagnosed problems.

 f. Resolve any previous outstanding problems.

1.7.4   Scheduled Work

This work shall be performed during regular working hours, Monday through Friday, excluding legal holidays.

1.7.5   Emergency Service

The Government will initiate service calls when the system is not functioning properly. Qualified personnel shall be available to provide service to the system. A telephone number where the service supervisor can be reached at all times shall be provided. Service personnel shall be at the site within 24 hours after receiving a request for service. The control system shall be restored to proper operating condition within three calendar days after receiving a request for service.

1.7.6   Operation

Scheduled adjustments and repairs shall include verification of the control system operation as demonstrated by the applicable tests of the performance verification test.

1.7.7   Records and Logs

Dated records and logs shall be kept of each task, with cumulative records for each major component, and for the complete system chronologically. A continuous log shall be maintained for all devices. The log shall contain initial analog span and zero calibration values and digital points. Complete logs shall be kept and shall be available for inspection onsite, demonstrating that planned and systematic adjustments and repairs have been accomplished for the control system.

1.7.8   Work Requests

Each service call request shall be recorded as received and shall include the serial number identifying the component involved, its location, date and time the call was received, nature of trouble, names of the service personnel assigned to the task, instructions describing what has to be done, the amount and nature of the materials to be used, the time and date work started, and the time and date of completion. A record of the work performed shall be submitted within 5 days after work is accomplished.

1.7.9   System Modifications

Recommendations for system modification shall be submitted in writing. No system modifications, including operating parameters and control settings, shall be made without prior approval of the Government. Any modifications made to the system shall be incorporated into the operations and maintenance manuals, and other documentation affected.

1.7.10   Software

Updates to the software shall be provided for system, operating and application software, and operation in the system shall be verified. Updates shall be incorporated into operations and maintenance manuals, and software documentation. There shall be at least one scheduled update near the end of the first year's warranty period, at which time the latest released version of the Contractor's software shall be installed and

validated.

PART 2   PRODUCTS

2.1   GENERAL EQUIPMENT REQUIREMENTS

Units of the same type of equipment shall be products of a single
manufacturer. Each major component of equipment shall have the
manufacturer's name and address, and the model and serial number in a
conspicuous place. Materials and equipment shall be standard products of a
manufacturer regularly engaged in the manufacturing of such products, which
are of a similar material, design and workmanship. The standard products
shall have been in a satisfactory commercial or industrial use for two
years prior to use on this project. The two years' use shall include
applications of equipment and materials under similar circumstances and of
similar size. The two years' experience shall be satisfactorily completed
by a product which has been sold or is offered for sale on the commercial
market through advertisements, manufacturers' catalogs, or brochures.
Products having less than a two-year field service record will be
acceptable if a certified record of satisfactory field operation, for not
less than 6,000 hours exclusive of the manufacturer's factory tests, can be
shown. The equipment items shall be supported by a service organization.
Items of the same type and purpose shall be identical, including equipment,
assemblies, parts and components. Automatic temperature controls shall be
direct digital controls that will provide the required sequence of
operation.

2.1.1   Electrical and Electronic Devices

Electrical, electronic, and electropneumatic devices not located within a
DDC panel shall have a NEMA ICS 1 enclosure in accordance with NEMA 250
unless otherwise shown.

2.1.2   Standard Signals

Except for air distribution terminal unit control equipment, the output of
all analog transmitters and the analog input and output of all DDC
controllers shall be 4-to-20 mAdc signals. The signal shall originate from
current-sourcing devices and shall be received by current-sinking devices.

2.1.3   Ambient Temperature Limits

DDC panels shall have ambient condition ratings of 1.7 to 49 degrees C 35
to 120 degrees Fand 10 to 95 percent relative humidity, noncondensing.
Devices installed outdoors shall operate within limit ratings of minus 37
to plus 66 degrees C. minus 35 to plus 150 degrees F. Instrumentation and
control elements shall be rated for continuous operation under the ambient
environmental temperature, pressure, humidity, and vibration conditions
specified or normally encountered for the installed location.

2.1.4   Year 2000 Compliance

All equipment and software shall be Year 2000 compliant and shall be able
to accurately process date/time data (including, but not limited to,
calculating, comparing, and sequencing) from, into, and between the
twentieth and twenty-first centuries, including leap year calculations,
when used in accordance with the product documentation provided by the

contractor, provided that all products (e.g. hardware, software, firmware) used in combination with other information technology, shall accurately process date/time data if other information technology properly exchanges date/time data with it.

2.2   WIRING

2.2.1   Terminal Blocks

Terminal blocks shall be insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, shall be suitable for rail mounting, and shall have end plates and partition plates for separation or shall have enclosed sides.

2.2.2   Control Wiring for 24-Volt Circuits

Control wiring for 24-volt circuits shall be 18 AWG minimum, stranded copper and shall be rated for 300-volt service.

2.2.3   Wiring for 120-Volt Circuits

Wiring for 120-volt circuits shall be 18 AWG minimum, stranded copper and shall be rated for 600-volt service.

2.2.4   Instrumentation Cable

Instrumentation cable shall be 18 AWG, stranded copper, single- or multiple-twisted, minimum 50 mm 2 inchlay of twist, 100 percent shielded pairs, and shall have a 300-volt insulation. Each pair shall have a 20 AWG tinned-copper drain wire and individual overall pair insulation. Cables shall have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.

2.2.5   Transformers

Step down transformers shall be utilized where control equipment operates at lower than line circuit voltage. Transformers, other than transformers in bridge circuits, shall have primaries wound for the voltage available and secondaries wound for the correct control circuit voltage. Transformer shall be sized so that the connected load is 80 percent of the rated capacity or less. Transformers shall conform to UL 508 and NEMA ST 1.

2.3   ACTUATORS

Actuators shall electric or electronic as shown and shall be provided with mounting and connecting hardware. Actuators shall fail to their spring-return positions on signal or power failure. The actuator stroke shall be limited in the direction of power stroke by an adjustable stop. Actuators shall have a visible position indicator. Actuators shall smoothly open or close the devices to which they are applied and shall have a full stroke response time of 90 seconds or less. Electric actuators shall have an oil-immersed gear train. Electric or electronic actuators operating in series shall have an auxiliary actuator driver. Electric or electronic actuators used in sequencing applications shall have an adjustable operating range and start point.

2.3.1   Valve Actuators

Valve actuators shall be selected to provide a minimum of 125 percent of the motive power necessary to operate the valve over its full range of operation.

2.4   AUTOMATIC CONTROL VALVES

Valves shall have stainless-steel stems and stuffing boxes with extended necks to clear the piping insulation. Unless otherwise stated, valves shall have globe style bodies. Valve bodies shall be designed for not less than 862 kPa 125 psigworking pressure or 150 percent of the system operating pressure, whichever is greater. Valve leakage rating shall be 0.01 percent of rated KvCv. Unless otherwise specified, bodies for valves 40 mm 1-1/2 inchesand smaller shall be brass or bronze, with threaded or union ends; bodies for 50 mm 2 inchvalves shall have threaded ends; and bodies for valves 50 to 80 mm 2 to 3 inches shall be of brass, bronze or iron. Bodies for valves 65 mm 2-1/2 inchesand larger shall be provided with flanged-end connections. Valve Kv Cvshall be within 100 to 125 percent of the Kv Cvshown.

2.4.1   Butterfly Valve Assembly

Butterfly valves shall be threaded lug type suitable for dead-end service and modulation to the fully-closed position, with carbon-steel bodies and noncorrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from minus 29 to plus 121 degrees C. minus 20 to plus 250 degrees F. Valves shall have a manual means of operation independent of the actuator. The rated Kv Cvfor butterfly valves shall be the value KvCv at 70% open (60 degrees open).

2.4.2   Two-Way Valves

Two-way modulating valves shall have equal-percentage characteristics.

2.4.3   Three-Way Valves

Three-way valves shall provide linear flow control with constant total flow throughout full plug travel.

2.4.4   Fan Coil Unit Valves

Control valves with either flare-type or solder-type ends shall be provided for duct or terminal-unit coils. Flare nuts shall be furnished for each flare-type end valve.

2.4.5   Valves for Chilled-Water Service

Internal valve trim shall be bronze except that valve stems may be type 316 stainless steel. Valve Kv Cvshall be within 100 to 125 percent of the Kv Cv shown. Valves 100 mm 4 inchesand larger shall be butterfly.

2.4.6   Valves for Hot-Water Service

For hot water service below 122 degrees C250 degrees F, internal trim (including seats, seat rings, modulating plugs, and springs) 210 degrees F shall be Type 316 stainless steel. Nonmetallic parts of hot-water control

valves shall be suitable for a minimum continuous operating temperature of
121 degrees C 250 degrees For 28 degrees C 50 degrees Fabove the system
design temperature, whichever is higher. Valves 100 mm 4 inches and larger
shall be butterfly valves.

2.5   DAMPERS

2.5.1   Damper Assembly

A single damper section shall have blades no longer than 1.2 meters 48
inchesand shall be no higher than 1.8 meters. 72 inches. Maximum damper
blade width shall be 203 mm. 8 inches. Larger sizes shall be made from a
combination of sections. Dampers shall be steel, or other materials where
shown. Flat blades shall be made rigid by folding the edges.
Blade-operating linkages shall be within the frame so that blade-connecting
devices within the same damper section shall not be located directly in the
air stream. Damper axles shall be 13 mm 0.5 inchminimum, plated steel rods
supported in the damper frame by stainless steel or bronze bearings.
Blades mounted vertically shall be supported by thrust bearings. Pressure
drop through dampers shall not exceed 10 Pa 0.04 inch water gaugeat 5.1 m/s
1,000 feet per minute in the wide-open position. Frames shall not be less
than 50 mm 2 inchesin width. Dampers shall be tested in accordance with
AMCA Std 500.

2.5.2   Operating Links

Operating links external to dampers, such as crankarms, connecting rods,
and line shafting for transmitting motion from damper actuators to dampers,
shall withstand a load equal to at least twice the maximum required
damper-operating force. Rod lengths shall be adjustable. Links shall be
brass, bronze, zinc-coated steel, or stainless steel. Working parts of
joints and clevises shall be brass, bronze, or stainless steel.
Adjustments of crankarms shall control the open and closed positions of
dampers.

2.5.3   Damper Types

Dampers shall be parallel-blade type.

2.5.3.1   Outside Air, Return Air, and Relief Air Dampers

Outside air, return air and relief air dampers shall be provided where
shown. Blades shall have interlocking edges and shall be provided with
compressible seals at points of contact. The channel frames of the dampers
shall be provided with jamb seals to minimize air leakage. Dampers shall
not leak in excess of 102 L/s per square meter 20 cfm per square footat
1017 Pa 4 inches water gaugestatic pressure when closed. Seals shall be
suitable for an operating temperature range of minus 40 to plus 94 degrees
C. minus 40 to plus 200 degrees F. Dampers shall be rated at not less than
10 m/s 2,000 feet per minuteair velocity.

2.5.3.2   Mechanical and Electrical Space Ventilation Dampers

Mechanical and electrical space ventilation dampers shall be as shown.
Dampers shall not leak in excess of 406 L/s per square meter 80 cfm square
footat 1017 Pa 4 inches water gauge static pressure when closed. Dampers
shall be rated at not less than 7.6 m/s 1,500 feet per minuteair velocity.

2.6   SMOKE DETECTORS

Duct smoke detectors shall be provided in supply air ducts in accordance
with NFPA 90A. Duct smoke detectors shall conform to the requirements of
UL 268A. Duct smoke detectors shall have perforated sampling tubes
extended into the air duct. Detector circuitry shall be mounted in a
metallic enclosure exterior to the duct. Detectors shall have manual
reset. Detectors shall be rated for air velocities that include air flows
between 2.5 and 20 m/s. [500 and 4000] [_____] fpm. Detectors shall be
powered from the HVAC control panel. Detectors shall have two sets of
normally open alarm contacts and two sets of normally closed alarm
contacts. Detectors shall be connected to the building fire alarm panel
for alarm initiation. A remote annunciation lamp and accessible remote
reset switch shall be provided for duct detectors that are mounted eight
feet or more above the finished floor and for detectors that are not
readily visible. Remote lamps and switches as well as the affected fan
units shall be properly identified in etched rigid plastic placards.

2.7   INSTRUMENTATION

2.7.1   Measurements

Transmitters shall be calibrated to provide the following measurements,
over the indicated ranges, for an output of 4 to 20 mAdc:

    a.   Conditioned space temperature, from 10 to 30 degrees C50 to 85
degrees F.

    b.   Duct temperature, from 5 to 60 degrees C40 to 140 degrees F.

    c.   Chilled-water temperature, from minus 1 to plus 38 degrees C.

    d.   Heating hot-water temperature, from 10 to 121 degrees C50 to 250
degrees F.

    e.   Condenser-water temperature, from minus 1 to plus 55 degrees C30
to 130 degrees F.

    f.   Outside-air temperature, from minus 35 to plus 55 degrees Cminus
30 to 130 degrees F.

2.7.2   Temperature Instruments

2.7.2.1   Resistance Temperature Detectors (RTD)

Temperature sensors shall be 100 ohms 3- or 4-wire RTD. Each RTD shall be
platinum with a tolerance of 0.30 degrees C 0.54 degrees Fat 0 degrees C 32
degrees Fwith a temperature coefficient of resistance (TCR) of .00385
ohms/ohm/deg C .00214 ohms/ohm/deg Fand shall be encapsulated in epoxy,
series 300 stainless steel, anodized aluminum, or copper. RTD for chilled
water storage tank shall be equipped and sealed for sumbersible type
application. Each RTD shall be furnished with an RTD transmitter as
specified, integrally mounted unless otherwise shown.

2.7.2.2   Continuous Averaging RTD

Continuous averaging RTDs shall have a tolerance of plus or minus 0.5

degrees C 1.0 degree Fat the reference temperature, and shall be of
sufficient length to ensure that the resistance represents an average over
the cross section in which it is installed. The sensing element shall have
a bendable copper sheath. Each averaging RTD shall be furnished with an
RTD transmitter to match the resistance range of the averaging RTD.

2.7.2.3   RTD Transmitter

The RTD transmitter shall match the resistance range of the RTD. The
transmitter shall be a two-wire, loop powered device. The transmitter
shall produce a linear 4-to-20 mAdc output corresponding to the required
temperature measurement. The output error shall not exceed 0.1 percent of
the calibrated measurement.

2.7.3   Thermowells

Thermowells shall be Series 300 stainless steel with threaded brass plug
and chain, 50 mm 2 inchlagging neck and extension type well. Inside
diameter and insertion length shall be as required for the application.

2.7.4   Sunshields

Sunshields for outside air temperature sensing elements shall prevent the
sun from directly striking the temperature sensing elements. The
sunshields shall be provided with adequate ventilation so that the sensing
element responds to the ambient temperature of the surroundings. The top
of each sunshield shall have a galvanized metal rainshield projecting over
the face of the sunshield. The sunshields shall be painted white.

2.7.5   Differential Pressure Instruments

The instrument shall be a pressure transmitter with an integral sensing
element. The instrument over pressure rating shall be 300 percent of the
operating pressure. The sensor/transmitter assembly accuracy shall be plus
or minus two percent of full scale. The transmitter shall be a two-wire,
loop-powered device. The transmitter shall produce a linear 4-to-20 mAdc
output corresponding to the required pressure measurement.

2.8   THERMOSTATS

Thermostat ranges shall be selected so that the setpoint is adjustable
without tools between plus or minus 5 degrees C 10 degrees Fof the setpoint
shown. Thermostats shall be electronic or electric.

2.8.1   Nonmodulating Room Thermostats

Contacts shall be single-pole double-throw (SPDT), hermetically sealed, and
wired to identified terminals. Maximum differential shall be 3 degrees C.
5 degrees F. Room thermostats shall be enclosed with separate locking
covers (guards).

2.8.2   Modulating Room Thermostats

Modulating room thermostats shall have either one output signal, two output
signals operating in unison, or two output signals operating in sequence,
as required for the application. Each thermostat shall have an adjustable
throttling range of 2 to 4 degrees C 4 to 8 degrees Ffor each output. Room

thermostats shall be enclosed with separate locking covers (guards).

2.8.3   Nonmodulating Capillary Thermostats and Aquastats

Each thermostat shall have a capillary length of at least 1500 mm5 feet,
shall have adjustable direct-reading scales for both setpoint and
differential, and shall have a differential adjustable from 3 to 9 degrees
C. 6 to 16 degrees F. Aquastats shall be of the strap on type, with 5
degrees C 10 degrees Ffixed differential.

2.8.4   Freezestats

Freezestats shall be manual reset, low temperature safety thermostats, with
NO and NC contacts and a 6000 mm 20 footelement which shall respond to the
coldest 450 mm 18 inchsegment.

2.8.5   Modulating Capillary Thermostats

Each thermostat shall have either one output signal, two output signals
operating in unison, or two output signals operating in sequence, as
required for the application. Thermostats shall have adjustable throttling
ranges of 2 to 4 degrees C 4 to 8 degrees Ffor each output.

2.8.6   Fan-Coil Unit Room Thermostats

Fan-coil unit thermostats in personnel living spaces shall be of the low
voltage type with locking covers. Electrical rating shall not exceed 2.5
amperes at 30 volts ac. Housing shall be corrosion resisting metal or
molded plastic. Transformer and fan relay shall be provided for the proper
operation of each thermostatic control system as necessary to suit the
design of the control system using the thermostats specified below. Either
separate heating thermostats and separate cooling thermostats or dual
element heating cooling thermostats may be provided. Motor speed switches
shall be provided for three-speed fan control.

2.8.6.1   Heating Thermostat

Fan-coil heating thermostats shall be provided with fixed heat anticipation
and shall have a single-pole, single-throw (SPST) switch hermetically
sealed and actuated by a bimetallic or bellows type element. Thermostats
shall be provided with external temperature setting devices with a factory
set maximum of 22 degrees C. [72] [68] degrees F.Heating thermostats shall
have an adjustable range of at least 7 degrees below 22 degrees C. 13
degrees below [72] [68] degrees F.

2.8.6.2   Cooling Thermostat

Fan-coil cooling thermostats shall be provided with fixed cooling
anticipation heater and shall have a single-pole, single-throw (SPST)
switch hermetically sealed and actuated by a bimetallic or bellows type
element. Thermostats shall be provided with external temperature setting
devices with a factory set minimum of 25 degrees C. 78 degrees F. Cooling
thermostats shall have an adjustable range of at least 4 degrees above 25
degrees C. 7 degrees above 78 degrees F.

2.8.6.3   Combination Thermostat

Fan coil unit combination heating-cooling thermostats shall be provided
with separate temperature sensing elements for each system, and shall have
a single-pole, single-throw (SPST) switch, hermetically sealed and actuated
by a bimetallic or bellows type element. Each element shall operate
switches to provide single stage control for heating and cooling. Scales
and ranges shall be as specified for individual thermostats. Thermostats
shall contain, or a subbase shall be provided which contains, selector
switches for Heat-Off-Cool. A limited range heating-cooling dead band
thermostat shall control cooling when temperature is above the upper
setpoint and heating when temperature is below the lower setpoint and shall
have a dead band, with no heating or cooling, when temperature is between
the setpoints. Setpoint adjustment shall be concealed.

2.9   PRESSURE SWITCHES

2.9.1   Differential-Pressure Switches

Each switch shall be an adjustable diaphragm-operated device with two SPDT
contacts, with taps for sensing lines to be connected to duct pressure
fittings designed to sense air pressure. These fittings shall be of the
angled-tip type with tips pointing into the air stream. The setpoint shall
not be in the upper or lower quarters of the range and the range shall not
be more than three times the setpoint. Differential shall be a maximum of
35 Pa0.15 inch water gauge at the low end of the range and 85 Pa 0.35 inch
water gaugeat the high end of the range.

2.10   INDICATING DEVICES

2.11.1   Thermometers

2.10.1.1   Piping System Thermometers

Piping system thermometers shall have brass, malleable iron or aluminum
alloy case and frame, clear protective face, permanently stabilized glass
tube with indicating-fluid column, white face, black numbers, and a 230 mm
9 inch scale. Thermometers for piping systems shall have rigid stems with
straight, angular, or inclined pattern.

2.10.1.2   Piping System Thermometer Stems

Thermometer stems shall have expansion heads as required to prevent
breakage at extreme temperatures. On rigid-stem thermometers, the space
between bulb and stem shall be filled with a heat-transfer medium.

2.10.1.3   Nonaveraging Air-Duct Thermometers

Air-duct thermometers shall have perforated stem guards and 45-degree
adjustable duct flanges with locking mechanism.

2.10.1.4   Averaging Air-Duct Thermometers

Averaging thermometers shall have a 90 mm 3-1/2 inch(nominal) dial, with
black legend on white background, and pointer traveling through a
270-degree arc.

2.10.1.5   Accuracy

Thermometers shall have an accuracy of plus or minus one percent of scale range. Thermometers shall have a range suitable for the application.

2.10.2   Pressure Gauges

Gauges shall be 50 mm 2 inch(nominal) size, back connected, suitable for field or panel mounting as required, shall have black legend on white background, and shall have a pointer traveling through a 270-degree arc. Accuracy shall be plus or minus three percent of scale range. Gauges shall meet requirements of ASME B40.1.

2.10.2.1   Hydronic System Gauges

Gauges for hydronic system applications shall have ranges and graduations as shown.

2.10.3   Low Differential Pressure Gauges

Gauges for low differential pressure measurements shall be a minimum of 90 mm 3.5 inch(nominal) size with two sets of pressure taps, and shall have a diaphragm-actuated pointer, white dial with black figures, and pointer zero adjustment. Gauges shall have ranges and graduations as shown. Accuracy shall be plus or minus two percent of scale range.

2.11   CONTROL DEVICES AND ACCESSORIES

2.11.1   Relays

Control relay contacts shall have utilization category and ratings selected for the application, with a minimum of two sets of contacts (two normally open, two normally closed) enclosed in a dustproof enclosure. Relays shall be rated for a minimum life of one million operations. Operating time shall be 20 milliseconds or less. Relays shall be equipped with coil transient suppression devices to limit transients to 150 percent of rated coil voltage. Time delay relays shall be 2PDT with eight-pin connectors, dust cover, and a matching rail-mounted socket. Adjustable timing range shall be 0 to 5 minutes. Power consumption shall not be greater than three watts.

2.11.2   Current Sensing Relays

Current sensing relays shall provide a normally-open contact rated at a minimum of 50 volts peak and 1/2 ampere or 25 VA, noninductive. There shall be a single hole for passage of current carrying conductors. The devices shall be sized for operation at 50 percent rated current based on the connected load. Voltage isolation shall be a minimum of 600 volts.

2.12   DIRECT DIGITAL CONTROL (DDC) HARDWARE

All functions, constraints, data base parameters, operator developed programs and any other data shall be downloadable from a laptop PC to network control panels, RIU's, and universal programmable controllers. Download shall be accomplished through both the primary network and the local DDC laptop PC port.

2.12.1   Network Control Panel

Network Control Panels shall utilize peer-to-peer communications over the Echelon LON network and meet Lon Mark Interoperability Association Standards. The controllers will have standard LNS plug in software. Network control panels shall be microcomputer-based with sufficient memory provided to perform all specified and shown network control panel functions and operations, including spare capacity for all spares and its I/O functions specified. Each network control panel and remote I/O units (RIU) shall have a minimum of 10% of its I/O functions as spare capacity but not less than 2 of each type used in each. The type of spares shall be in the same proportion as the implemented I/O functions on the panel, but in no case shall there be less than two spare points of each type. The panel I/O functions shall be furnished complete, with no changes or additions necessary to support implementation of spare functions. Output relays associated with digital signals shall be considered part of the I/O function, whether physically mounted in the enclosure or separately mounted. Implementation of spare points shall necessitate only providing the additional field sensor or control device, field wiring including connection to the system, and point definition assignment by the operator using the central workstation/tester or laptop PC. The panel shall contain all necessary I/O functions to connect to field sensors and control panels. I/O function operation shall be fully supervised to detect I/O function failures. Network control panels shall operate in an independent stand-alone mode, which is defined as all network control panel operations performed by the network control panel without any continuing input from other Direct digital controls or laptop PC. The network control panel shall be capable of controlling a mix of at least 32 RIUs, and universal programmable controllers. Provide an acoustic touch screen on one control panel in each mechanical room that is capable and does in fact display the entire system's control points as a dynamic data man-machine interface. Screen shall be at least 200mm x 200mm.

2.12.1.1   Integral Features

The network control panel shall include:

    a.   Main power switch.

    b.   Power on indicator.

    c.   Laptop PC port, connector, and if necessary power supply.

    d.   Manufacturers control network port.

    e.   An intrusion detection device, connected as an alarm.

2.12.1.2   Communication Interfaces

The following communication capabilities shall function simultaneously.

     a.   Manufacturers Control Network. Manufacturers control network within a building shall be Echelon LONWORKS based on Echelon's LNS network operating system with communications interfaces for each data transmission systems (DTS) circuit between network control panels and RIUs, unitary controllers, and universal programmable controllers, shall be provided. Communication interfaces shall be provided between each network control panel and associated I/O functions. The DTS will provide for transmission speeds necessary to comply with performance requirements specified. DTS

equipment shall be installed in the network control panel enclosure.

     b. A laptop PC Port. A communications port for interfacing to a laptop PC shall be provided. Network control panel laptop PC port other than RS-232, shall be converted to RS-232, including cabling and power supply, and shall be permanently installed in the panel.

     c. Primary Network Port. The network control panel shall either have a built in primary network Port or be capable of accepting a primary network port expansion card and shall be connected to the installation's network for the base wide utility monitoring and control system (UMCS). This shall be accessible from any web browser with the correct security password as well as from the existing central PC which contains the archived database for the lon system. The primary network port expansion card shall be Ethernet (IEEE802.3).

2.12.1.3   Memory and Real Time Clock (RTC) Backup

The network control panel memory and real time clock functions shall continue to operate for a minimum of 72 hours in the event of a power failure. If rechargeable batteries are provided, automatic charging of batteries shall be provided. Whenever a either a permanent workstation/tester or laptop PC is monitoring the network control panel, a low battery alarm message shall be sent to it.

2.12.1.4   Duplex Outlet

A single phase, 120 Vac electrical service outlet for use with test equipment shall be furnished either inside or within 2 meters 6 feetof the network control panel enclosure.

2.12.1.5   Locking Enclosures

Locking type mounting cabinets with common keying shall be furnished for each network control panel.

2.12.1.6   Failure Mode

Upon failure of the network control panel, either due to failure of the network control panel hardware or of the manufacturers control network, the network control panel shall revert to the failure mode as shown.

     a. Manufacturers Control Network Failure: Upon failure of the manufacturers control network, the network control panel shall operate in an independent stand-alone mode.

     b. Network Control Panel Hardware Failure: Upon failure of the network control panel hardware, the network control panel shall cease operation and stop communications with other network control panels, RIUs, and universal programmable controllers connected to the affected network control panel. The affected network control panel shall respond to this failure as specified and shown.

2.12.2   Remote I/O Unit (RIU)

Network Controllers shall utilize peer-to-peer communications over the Echelon LON network and meet Lon Mark Interoperability Association

Standards. The controllers will have standard LNS plug in software. The RIU shall be functionally a part of the network control panel as specified, but may be remotely located from the network control panel and communicate over a dedicated communication circuit. When remotely located, the I/O functions shall be subject to the same requirements as for the network control panel hardware. RIUs shall be used to connect remote inputs and outputs to a network control panel and shall contain all necessary I/O functions to connect to field sensors and control devices. RIU operation shall be fully supervised by the network control panel to detect failures. Each RIU shall have a minimum of 10 % of its I/O functions as spare capacity. The type of spares shall be in the same proportion as the implemented I/O functions on the RIU, but in no case shall there be less than two spare points of each type. The RIU shall be furnished complete, with no changes or additions necessary to support implementation of spare functions. Output relays associated with digital signals shall be considered part of the I/O function, whether physically mounted in the enclosure or separately mounted. Implementation of spare points by others shall require only providing the additional field sensor or control device, field wiring including connection to the system, and point definition assignment by the operator. The RIU shall either report the status of all connected points on each scan, or report the status of all points which have changed state or value since the previous scan.

2.12.2.1   Integral Features

The RIU shall include:

   a.   Main power switch.

   b.   Power on indicator.

   c.   Laptop PC port, connector, and if necessary power supply.

   d.   Manufacturers control network port.

   e.   An intrusion detection device, connected as an alarm.

2.12.2.2   Duplex Outlet

A single phase, 120 Vac electrical service outlet for use with test equipment shall be furnished either inside or within 2 meters 6 feetof the RIU.

2.12.2.3   Locking Enclosures

Locking type mounting cabinets with common keying shall be furnished for each RIU.

2.12.2.4   Failure Mode

Upon failure of the RIU, either due to failure of the RIU hardware or of the DTS, the RIU shall revert to the failure mode shown.

2.12.3   Universal Programmable Controller (UPC)

Network Controllers shall utilize peer-to-peer communications over the Echelon LON network and meet Lon Mark Interoperability Association

Standards. The controllers will have standard LNS plug in software. The universal programmable controller shall be a microprocessor based controller designed and programmed to control and monitor systems as shown. Resident programs shall be contained in reprogramable nonvolatile memory. Each universal programmable controller shall contain necessary power supplies, transformers, memory, I/O functions and communications interfaces necessary to perform its required functions and to provide control and monitoring of connected equipment and devices. It shall contain all necessary I/O functions to connect to field sensors and controls. I/O operation shall be fully supervised to detect I/O function failures. It shall provide for operation as a device connected to the system via the manufacturers control network.

2.12.3.1   Integral Features

The universal programmable controller shall include as a minimum:

     a.   Main power switch.

     b.   Power on indicator.

     c.   Laptop PC port, connector, and if necessary power supply.

     d.   Manufacturers control network port.

     e.   I/O functions

        (1)   8 DI

        (2)   4 DO

        (3)   8 AI

        (4)   4 AO

        (5)   1 PA

2.12.3.2   Communication Interfaces

The UPC shall be Echelon LONWORKS based on Echelon's LNS network operating system and have the following communication capabilities which shall function simultaneously.

    a.   Manufacturers Control Network. The manufacturers control network communications interface for a data transmission systems (DTS) circuit between the UPC and a network control panels shall be provided. The DTS will provide for transmission speeds necessary to comply with performance requirements specified. DTS equipment shall be installed in the UPC Panel enclosure.

    b.   Laptop PC Port. A communications port for interfacing to a laptop PC shall be provided. A UPC laptop PC port other than RS-232, shall be converted to RS-232, including cabling and power supply, and shall be permanently installed in the panel.

2.12.3.3   Memory and RTC Backup

The UPC memory and real time clock functions shall continue to operate for
a minimum of 72 hours in the event of a power failure. If rechargeable
batteries are provided, automatic charging of batteries shall be provided.
Whenever a portable workstation/tester is monitoring the network control
panel, a low battery alarm message shall be sent to it.

2.12.3.4   Specific Requirements

Each universal programmable controller shall be accessible for purposes of
application selection, control parameters, set point adjustment, and
monitoring from any DDC controller connected to the same manufacturers
control network as the universal programmable controller. This shall be
done using a portable workstation/tester connected to a portable
workstation/tester port either directly or via modem.

2.12.3.5   Locking Enclosures

Locking type mounting cabinets with common keying shall be furnished for
each enclosure.

2.12.3.6   Failure Mode

Upon failure of the universal programmable controller, it shall revert to
the failure mode of operation as shown.

2.12.4   Chiller Control Panel

Chiller control panel shall utilize peer-to-peer communications over the
Echelon LON network and meet Lon Mark Interoperability Association
Standards. The controllers will have standard LNS plug in software and
shall provide, both locally and through the Manufacturers Control Network,
the control, monitoring, and safety equipment functions provided by the
chiller manufacturer's control panel(s) (two communications ports total).
The chiller control panel instrumentation and control ranges and accuracies
shall match those of the chiller manufacturer's control devices. The
chiller panel shall have a communication port for interface to a laptop PC
through either the Manufacturers Control Network or modem for chiller(s)
start/stop, chilled water temperature reset, and monitoring of chiller
operating status, alarms, and power consumption.

2.12.5   I/O Functions

2.12.5.1   DDC Hardware I/O Functions

I/O Functions shall be provided as part of the DDC system and shall be in
accordance with the following:

     a. The analog input (AI) function shall monitor each analog input,
perform A-to-D conversion, and hold the digital value in a buffer for
interrogation. The A-to-D conversion shall have a minimum resolution of 10
bits plus sign. Signal conditioning shall be provided for each analog
input. Analog inputs shall be individually calibrated for zero and span,
in hardware or in software. The AI shall incorporate common mode noise
rejection of 50 dB from 0 to 100 Hz for differential inputs, and normal
mode noise rejection of 20 dB at 60 Hz from a source impedance of 10,000
ohms. Input ranges shall be within the range of 4-to-20 mAdc.

b. The analog output (AO) function shall accept digital data, perform D-to-A conversion, and output a signal within the range of 4-to-20 mAdc. D-to-A conversion shall have a minimum resolution of eight bits plus sign. Analog outputs shall be individually calibrated for zero and span. Short circuit protection on voltage outputs and open circuit protection on current outputs shall be provided.

c. The digital input (DI) function shall accept on-off, open-close, or other change of state (two state data) indications. Isolation and protection against an applied steady-state voltage up to 180 Vac peak shall be provided.

d. The digital output (DO) function shall provide contact closures for momentary and maintained operation of output devices. Closures shall have a minimum duration of 0.1 second. DO relays shall have an initial breakdown voltage between contacts and coil of at least 500 V peak. Electromagnetic interference suppression shall be furnished on all output lines to limit transients to nondamaging levels. Protection against an applied steady-state voltage up to 180 Vac peak shall be provided. Minimum contact rating shall be one ampere at 24 Vac.

e. The pulse accumulator function shall have the same characteristics as the DI. In addition, a buffer shall be provided to totalize pulses and allow for interrogation by the DDC system. The pulse accumulator shall accept rates up to 20 pulses per second. The totalized value shall be reset to zero upon operator's command.

f. Signal conditioning for sensors shall be provided as specified.

g. The binary coded decimal (BCD) function: The BCD function shall have the same characteristics as the DI, except that, in addition, a buffer shall be provided to totalize inputs and allow for interrogation by the network control panel. The BCD function shall have 16-channel optically isolated buffered inputs to read four digit numbers. The BCD function shall accumulate inputs at rates up to 10 inputs per second.

2.12.5.2   Failure Mode

Upon failure of the I/O function, including data transmission failure, logic power supply failure, DDC processor malfunction, software failure, interposing relay power failure, or any other failure which prevents stand alone operation of any DDC normally capable of stand alone operation, connected outputs shall be forced to the failure mode shown.

2.12.6   Chiller Control Panel

Chiller control panel shall utilize peer-to-peer communications over the Echelon LON network and meet Lon Mark Interoperability Association Standards. The controllers will have standard LNS plug in software and shall provide, both locally and through the Manufacturers Control Network, the control, monitoring, and safety equipment functions provided by the chiller manufacturer's control panel(s) (two communications ports total). The chiller control panel instrumentation and control ranges and accuracies shall match those of the chiller manufacturer's control devices. The chiller panel shall have a communication port for interface to a laptop PC through either the Manufacturers Control Network or modem for chiller(s) start/stop, chilled water temperature reset, and monitoring of chiller operating status, alarms, and power consumption.

2.12.7   Boiler Control Panel

  Boiler control panel shall utilize peer-to-peer communications over the
  Echelon LON network and meet Lon Mark Interoperability Association
  Standards.   The controllers will have standard LNS plug in software, be
  microprocessor-based and shall provide, both locally and through the
  Manufacturers Control Network, the control, monitoring, and safety
  equipment functions provided by the boiler manufacturer's control panel(s)
  (two communications ports total).   The boiler control panel instrumentation
  and controls ranges and accuracies shall match those of the boiler
  manufacturer's control devices.   The boiler panel shall have a
  communication port for interface to a laptop PC through either the
  Manufacturers Control Network or modem for boiler(s) and start/stop, boiler
  water temperature reset, and monitoring of boiler operating status, alarms.

2.12.8   Laptop PC

  A laptop personnel computer (PC) shall be provided and shall be able to
  connect to any DDC hardware.   The laptop PC shall consist of 800 MHz
  Pentium IV processor, 512 MB SDRAM, 30 GB Hard Drive, minimum 6x4x4 CD
  Read-Writable, internal or external, 3.5 inch diskette, internal or
  external, 15 inch color display, Ultra XGA, Parallel and USB Serial Ports,
  Windows XP or or Windows 2000 Operating System, Network Management,
  Communiations and Utility Software, integral pointing device, color VGA
  video port for an external color monitor, 56K modem, PCMCIA type 3 slot,
  rechargeable battery, battery charger and 120 Vac power supply.   It shall
  include carrying case, extra battery, charger and a compatible network
  adapter.   The laptop PC shall:

      a.   Run DDC diagnostics.

      b.   Load all DDC memory resident programs and information, including
  parameters and constraints.

      c.   Display any AI, DI, AO, DO, or PA point in engineering units for
  analog points or status for digital points.

      d.   Control any AO or DO.

      e.   Provide an operator interface, contingent on password level,
  allowing the operator to use full English language words and acronyms, or
  an object oriented graphical user interface.

      f.   Display database parameters.

      g.   Modify database parameters.

      h.   Accept DDC software and information for subsequent loading into a
  specific DDC.   Provide all necessary software and hardware required to
  support this function, including an EIA ANSI/EIA/TIA 232-F port.

      i.   Disable/enable each DDC.

      j.   Perform all workstation functions as specified.

2.13   DDC SOFTWARE

All DDC software described in this specification shall be furnished as part
of the complete DDC System.

2.13.1   Operating System

LonMaker for Windows shall be used to design, commission, operate, and
maintain the multi-vendor, open, interoperable LONWORK control network.
This software will be turned over to the owner (with full documentation)
and licence as an operation and maintenance tool. Each DDC shall contain
an operating system that controls and schedules that DDC's activities in
real time. The DDC shall maintain a point database in its memory that
includes all parameters, constraints, and the latest value or status of all
points connected to that DDC. The execution of DDC application programs
shall utilize the data in memory resident files. The operating system
shall include a real time clock function that maintains the seconds,
minutes, hours, date and month, including day of the week. Each DDC real
time clock shall be automatically synchronized with the network control
panel real time clock at least once per day to plus or minus 10 seconds.
When the network control panel is connected to a central
workstation/tester, the network control panel RTC shall be updated by the
central workstation/tester RTC. The time synchronization shall be
accomplished without operator intervention and without requiring system
shutdown. The operating system shall allow loading of software, data files
data entry, and diagnostics from the central workstation/tester both
locally through the central workstation/tester port and remotely through a
network control panel and the manufacturers control network.

2.13.1.1   Startup

The DDC shall have startup software that causes automatic commencement of
operation without human intervention, including startup of all connected
I/O functions. A DDC restart program based on detection of power failure
at the DDC shall be included in the DDC software. Upon restoration of
power to the DDC, the program shall restart equipment and restore loads to
the state at time of power failure, or to the state as commanded by time
programs or other overriding programs. The restart program shall include
start time delays between successive commands to prevent demand surges or
overload trips. The startup software shall initiate operation of self-test
diagnostic routines. Upon failure of the DDC, if the database and
application software are no longer resident or if the clock cannot be read,
the DDC shall not restart and systems shall remain in the failure mode
indicated until the necessary repairs are made. If the database and
application programs are resident, the DDC shall resume operation after an
adjustable time delay of from 0 to 600 seconds. The startup sequence for
each DDC shall include a unique time delay setting for each control output
when system operation is initiated.

2.13.1.2   Operating Mode

Each DDC shall control and monitor functions as specified, independent of
communications with other DDC. This software shall perform all DDC
functions and DDC resident application programs as specified using data
obtained from I/O functions and based upon the DDC real time clock
function. When communications circuits between the DDC are operable, the
DDC shall obtain real time clock updates and any required global data
values transmitted from other network control panels. The DDC software
shall execute commands after performing constraints checks in the DDC.
Status and analog values, including alarms and other data shall be

transmitted from other network control panels when communications circuits are operable. If communications are not available, each DDC shall function in stand-alone mode and operational data, including the latest status and value of each point and results of calculations, normally transmitted from other network control panels shall be stored for later transmission to the network control panel. Storage for the latest 256 values shall be provided at each network control panel. Each DDC shall accept software downloaded from the network control panel. Constraints shall reside at the DDC.

2.13.1.3   Failure Mode

Upon failure for any reason, each DDC shall perform an orderly shutdown and force all DDC outputs to a predetermined (failure mode) state, consistent with the failure modes shown and the associated control device.

2.13.2   Functions

The Contractor shall provide software and hardware necessary to accomplish the following functions, as appropriate, fully implemented and operational, within each network control panel, RIU and universal programmable controller.

    a.   Scanning of inputs.

    b.   Control of outputs.

    c.   Reporting of analog changes outside a selectable differential.

    d.   Reporting of unauthorized digital status.

    e.   Reporting of alarms automatically to network control panel.

    f.   Reporting of I/O status to network control panel upon request.

    g.   Maintenance of real time, updated by the network control panel at least once a day.

    h.   Communication with the network control panel.

    i.   Execution of DDC resident application programs.

    j.   Averaging or filtering of AIs.

    k.   Constraints checks (prior to command issuance).

    l.   Diagnostics.

    m.   Laptop PC to controller operation as specified.

    n.   Reset of PA by operator based on time and value.

2.13.2.1   Analog Monitoring

The system shall measure and transmit analog values including calculated analog points. An analog change in value is defined as a change exceeding a preset differential value as specified. The record transmitted for each analog value shall include a readily identifiable flag which indicates the

abnormal status of the value when it deviates from operator selectable
upper and lower analog limits. Analog values shall be expressed in proper
engineering units with sign. Engineering units conversions shall be
provided for each measurement. Each engineering units conversion set shall
include range, span, and conversion equation. A vocabulary of engineering
unit descriptors shall be provided, using at least three alphanumeric
characters to identify information in the system. The system shall support
255 different engineering units.

2.13.2.2   Logic (Virtual) Points

Logic (virtual) points shall be software points entered in the point
database which are not directly associated with a physical I/O function.
Logic (virtual) points shall be analog or digital points created by
calculation from any combination of digital and analog points, or other
data having the properties of real points, including alarms, without the
associated hardware. Logic (virtual) points shall be defined or calculated
and entered into the database by the Contractor. The calculated analog
point shall have point identification in the same format as any other
analog point. The calculated point shall be used in any program where the
real value is not obtainable directly. Constants used in calculations
shall be changeable on-line by the operator. Calculated point values shall
be current for use by the system within 10 seconds of the time of any input
changes.

2.13.2.3   State Variables

If an analog point represents more than two (up to eight) specific states,
each state shall be nameable. For example, a level sensor shall be
displayed at its measured engineering units plus a state variable with
named states usable in programs or for display such as low
alarm/low/normal/high/high alarm.

2.13.2.4   Analog Totalization

Any analog point shall be operator assignable to the totalization program.
Up to eight analog values shall be totalized within a selectable time
period. At the end of the period, the totals shall be stored.
Totalization shall then restart from zero for the next time period. The
program shall keep track of the peak and total value measured during the
current period and for the previous period. The operator shall be able to
set or reset each totalized value individually. The time period shall be
able to be operator defined, modified or deleted on-line.

2.13.2.5   Energy Totalization

The system shall calculate the heat energy in Btus, for each energy source
consumed by the mechanical systems specified, totalize the calculated Btus,
the instantaneous rate in Btus per hour, and store totals in thousands of
Btus (MBtu). The Btus calculated shall be totalized for an adjustable time
period. The time period shall be defined uniquely for each Btu
totalization.

2.13.2.6   Trending

Any analog or calculated point shall be operator assignable to the trend
program. Up to eight points shall be sampled at individually assigned

intervals, selectable between one minute and two hours. A minimum of the
most recent 128 samples of each trended point shall be stored. The sample
intervals shall be able to be defined, modified, or deleted on-line.

2.13.3   I/O Point Database/Parameter Definition

Each I/O point shall be defined in a database residing in the DDC. The
definition shall include all physical parameters associated with each
point. Each point shall be defined and entered into the database by the
Contractor, including as applicable:

    a. Name.

    b. Device or sensor type (i.e., sensor, control relay, motors).

    c. Point identification number.

    d. Unit.

    e. Building number.

    f. Area.

    g. Island.

    h. DDC number and channel address.

    i. KW (running).

    j. KW (starting).

    k. Sensor range.

    l. Controller range.

    m. Sensor span.

    n. Controller span.

    o. Engineering units conversion (scale factor).

    p. Setpoint (analog).

    q. High reasonableness value (analog).

    r. Low reasonableness value (analog).

    s. High alarm limit differential (return to normal).

    t. Low alarm limit differential (return to normal).

    u. High alarm limit (analog).

    v. Low alarm limit (analog).

    w. Alarm disable time period upon startup or change of setpoint.

x. Analog change differential (for reporting).

y. Alarm class and associated primary message text.

z. High accumulator limit (pulse).

aa. Status description.

bb. Run time target.

cc. Failure mode as specified and shown.

dd. Constraints as specified.

2.13.4 Alarm Processing

Each DDC shall have alarm processing software for AI, DI, and PA alarms for all real and virtual points connected to that DDC.

2.13.4.1 Digital Alarms Definition

Digital alarms are those abnormal conditions indicated by DIs as specified and shown.

2.13.4.2 Analog Alarms Definition

Analog alarms are those conditions higher or lower than a defined value, as measured by an AI. Analog readings shall be compared to predefined high and low limits, and alarmed each time a value enters or returns from a limit condition. Unique high and low limits shall be assigned to each analog point in the system. Analog alarm limits shall be stored in the DDC database. Each analog alarm limit shall have an associated unique limit differential specifying the amount by which a variable must return into the proper operating range before being annunciated as a return-to-normal-state. All limits and differentials shall be entered on-line by the operator in limits of the measured variable, without interruption or loss of monitoring of the point concerned. The program shall automatically change the high or low limits or both, of any analog point, based on time scheduled operations as specified, allowing for a time interval before the alarm limit becomes effective. In CPA applications, key the limit to a finite deviation traveling with the setpoint. The system shall automatically suppress analog alarm reporting associated with a digital point when that digital point is turned off.

2.13.4.3 Pulse Accumulator Alarms Definition

Pulse accumulator alarms are those conditions calculated from totalized values of accumulator inputs or PA input rates that are outside defined limits as specified and shown. PA totalized values shall be compared to predefined limits and alarmed each time a value enters a limit condition. Unique limits shall be assigned to each PA point in the system. Limits shall be stored in the DDC database.

2.13.5 Constraints

2.13.5.1 Equipment Constraints Definitions

Each control point in the database shall have DDC resident constraints
defined and entered by the Contractor, including as applicable:

    a. Maximum starts (cycles) per hour.

    b. Minimum off time.

    c. Minimum on time.

    d. High limit (value in engineering units).

    e. Low limit (value in engineering units).

2.13.5.2   Constraints Checks

Control devices connected to the system shall have the DDC memory resident
constraints checked before each command is issued to insure that no
equipment damage will result from improper operation. Each command shall
be executed by the DDC only after all constraints checks have been passed.
Each command point shall have unique constraints assigned. High and low
"reasonableness" values or one differential "rate-of-change" value shall be
assigned to each AI. Values outside the reasonableness limits shall be
rejected and an alarm message sent to the network control panel or portable
workstation/tester. Status changes and analog point values shall be
reported to the workstation upon operator request, such as for reports,
alphanumeric displays, graphic displays, and application programs. Each
individual point shall be capable of being selectively disabled by the
operator from a workstation/tester. Disabling a point shall prohibit
monitoring and automatic control of that point.

2.13.6   Diagnostics

Each DDC shall have self-test diagnostic routines implemented in firmware.
The tests shall include routines that exercise memory. Diagnostic software
shall be usable in conjunction with the central workstation/tester and
portable workstation/tester. The software shall display messages in
English to inform the tester's operator of diagnosed problems.

2.13.7   Summer-Winter Operation Monitoring

The system shall provide software to automatically change the operating
parameters, monitoring of alarm limits, and start-stop schedules for each
mechanical system from summer to winter and vice-versa. The software shall
provide automatic commands to applications programs to coordinate proper
summer or winter operation. Change over setpoints shall be operator
selectable and settable.

2.13.8   Control Sequences and Control Loops

Sufficient memory shall be provided to implement the requirements specified
and shown for each DDC. Specific functions to be implemented are defined
in individual system control sequences and database tables shown in the
drawings, and shall include, as applicable, the following:

    a. PI Control: This function shall provide proportional control and
proportional plus integral control.

b. Two Position Control: This function shall provide control for a two state device by comparing a set point against a process variable and an established deadband.

c. Floating Point Control: This function shall exercise control when an error signal exceeds a selected deadband, and shall maintain control until the error is within the deadband limits.

d. Signal Selection: This function shall allow the selection of the highest or lowest analog value from a group of analog values as the basis of control. The function shall include the ability to cascade analog values so that large numbers of inputs can be reduced to one or two outputs.

e. Signal Averaging: This function shall allow the mathematical calculation of the average analog value from a group of analog values as the basis of control. The function shall include the ability to "weight" the individual analog values so that the function output can be biased as necessary to achieve proper control.

f. Reset Function: This function shall develop an AO based on up to two AIs and one operator specified reset schedule.

g. Cooling/Heating Operation Program: Software shall be provided to change, either automatically or on operator command, the operating parameters, monitoring of alarm limits, and start-stop schedules for each mechanical system where such a change from cooling to heating and vice versa is meaningful. The software shall provide commands to application programs to coordinate cooling or heating mode operation. Software shall automatically switch facilities from cooling to heating, and vice versa, based on schedules or temperatures. All HVAC equipment and systems shall be assigned to the program.

2.13.9 Command Priorities

A scheme of priority levels shall be provided to prevent interaction of a command of low priority with a command of higher priority. The system shall require the latest highest priority command addressed to a single point to be stored for a period of time longer than the longest time constraint in the on and off states, insuring that the correct command shall be issued when the time constraint is no longer in effect or report the rejected command. Override commands entered by the operator shall have higher priority than those emanating from applications programs.

2.13.10 Resident Application Software

The Contractor shall provide resident applications programs to achieve the sequences of operation, parameters, constraints, and interlocks necessary to provide control of the systems connected to the DDC system. Application programs shall be resident and shall execute in the DDC, and shall coordinate with each other, to insure that no conflicts or contentions remain unresolved. The Contractor shall coordinate the application programs specified with the equipment and controls operation, and other specified requirements. A scheme of priority levels shall be provided to prevent interaction of a command of low priority with a command of higher priority. The system shall require the latest highest priority command addressed to a single point to be stored for a period of time longer than the longest time constraint in the ON and OFF states, insuring that the correct command shall be issued when the time constraint is no longer in

effect or the rejected command shall be reported. Override commands
entered by the operator shall have higher priority than those emanating
from application programs.

2.13.10.1   Program Inputs and Outputs

The Contractor shall select the appropriate program inputs listed for each
application program to calculate the required program outputs. Where the
specific program inputs are not available, a "default" value or virtual
point appropriate for the equipment being controlled and the proposed
sequence of operation shall be provided to replace the missing input, thus
allowing the application program to operate. AIs to application programs
shall have an operator adjustable deadband to preclude short cycling or
hunting. Program outputs shall be real analog or digital outputs or logic
(virtual) points as required to provide the specified functions. The
Contractor shall select the appropriate input and output signals to satisfy
the requirements for control of systems as shown.

2.13.10.2   DDC General Conditions

The Contractor shall provide software required to achieve the sequences of
operation, parameters, constraints, and interlocks shown. Application
software shall be resident in the DDC in addition to any other required
software. In the event of a DDC failure, the controlled equipment shall
continue to function in the failure mode shown.

2.13.10.3   Scheduled Start/Stop Program

This program shall start and stop equipment based on a time of day schedule
for each day of the week, and on a holiday schedule. To eliminate power
surges, an operator adjustable time delay shall be provided between
consecutive start commands.

        a.   Program Inputs:

             (1)   Day of week/holiday.

             (2)   Time of day.

             (3)   Cooling and heating high-low alarm limits.

             (4)   Cooling and heating start-stop schedules.

             (5)   Cooling or heating mode of operation.

             (6)   Equipment status.

             (7)   Equipment constraints.

             (8)   Consecutive start time delay.

        b.   Program Outputs: Start/stop signal.

2.13.10.4   Day-Night Setback Program

The software shall limit the rise or drop of space temperature during
unoccupied hours. Whenever the space temperature is above (or below for

heating) the operator assigned temperature limit, the system shall be
turned on until the temperature is within the assigned temperature limit.

    a. Program Inputs:

        (1) Day of week.

        (2) Time of day.

        (3) Cooling or heating mode of operation.

        (4) Cooling and heating occupancy schedules.

        (5) Equipment status.

        (6) Space temperature.

        (7) Minimum space temperature during unoccupied periods.

        (8) Maximum space temperature during unoccupied periods.

        (9) Equipment constraints.

    b. Program Outputs: Start/stop signal.

2.13.10.5   Economizer Program

The software shall reduce the HVAC system cooling requirements when the OA
dry bulb temperature is less than the return air temperature. When the OA
dry bulb temperature is above the return air temperature or changeover
setpoint, the OA dampers, return air dampers, and relief air dampers shall
be positioned to provide minimum required OA. When the OA dry bulb
temperature is below a changeover setpoint temperature, the OA dampers,
return air dampers, and exhaust air dampers shall be positioned to maintain
the required mixed air temperature.

    a. Program Input:

        (1) Changeover conditions.

        (2) OA dry bulb temperature.

        (3) RA dry bulb temperature.

        (4) Mixed air dry bulb temperature.

        (5) Equipment constraints.

    b. Program Output: Damper actuator/cooling control signal.

2.13.10.6   Ventilation/Recirculation Programs

The software shall reduce the HVAC system thermal load for two modes of
operation as follows:

    a. Ventilation mode: In this mode, the system shall precool the

space prior to building occupancy. When the outside air temperature is lower than the space temperature, the outside air damper and exhaust air damper shall open to their maximum positions and the return air damper shall close to its minimum position.

     b. Recirculation mode: In this mode, the system shall preheat the space prior to building occupancy. When the outside air temperature is lower than the space temperature, the outside air damper and the exhaust air damper shall close to their minimum positions and the return air damper shall open to its maximum position.

     c. Program Inputs:

       (1) Day of week.

       (2) Time of day.

       (3) Cooling or heating mode of operation.

       (4) Equipment status.

       (5) Cooling and heating occupancy schedules.

       (6) OA dry bulb temperature.

       (7) Space temperature.

       (8) Equipment constraints.

     d. Program Output: Damper actuator control signal.

2.13.10.7   Hot Deck Temperature Reset Program

The software shall reset the hot deck temperature in accordance with the OA temperature. The hot deck supply temperature shall be reset downward or upward from a fixed temperature proportionally, as a function of OA temperature or other specified independent variable.

     a. Program Inputs:

       (1) Reset schedule.

       (2) Hot deck temperature.
       (3) Hot deck temperature setpoint.

       (4) OA dry bulb temperature.

     b. Program Outputs:

       (1) Hot deck valve actuator control signal.

2.13.10.8   Hot Water OA Reset Program

The software shall reset the hot water temperature supplied by the boiler in accordance with the OA temperature. The hot water supply temperature shall be reset downward or upward from a fixed temperature proportionally,

as a function of OA temperature.

    a. Program Inputs

        (1) Reset schedule.

        (2) OA dry bulb temperature.

        (3) Hot water supply temperature.

        (4) Maximum hot water supply temperature.

        (5) Minimum hot water supply temperature.

        (6) Equipment constraints.

    b. Program Output: Valve actuator control signal.

2.13.10.9   Chiller Sequencing/Optimization Program

Chiller program shall be used for chiller selection as well as control and
monitoring of chillers. The software shall sequence the lead chiller to
satisfy the cooling load, until the lead chiller is loaded as capacity as
indicated, the lag chiller shall then be selected. The program shall
follow the chiller manufacturer's startup and shutdown sequence
requirements. Interlocks between chilled water pumps, condenser water
pumps, and chiller shall be in accordance with the chiller manufacturer's
requirements

    a. Program Inputs

        (1) Efficiency curves.
        (2) Chiller water supply temperatures.
        (3) Chiller water return temperatures.
        (4) Entering condenser water temperatures.
        (5) Leaving condenser water temperatures.
        (6) Instantaneous KW to chillers.
        (7) Common chilled water supply temperatures.
        (8) Common chilled water return temperatures.
        (9) Chilled water pumps status.
        (10) Equipment constraints.

    b. Program Outputs

        (1) Start/stop signals for chillers (manual or automatic to
        control panel).
        (2) Start/stop signals for chilled water pumps (manual or
        automatic to control panel).
        (3) Start/stop signals for condenser water pumps (manual or
        automatic to control panel).
        (4) Start/stop signals for cooling tower fans (manual or automatic
        to control panel).
        (5) Chilled water supply temperature setpoint control signal.

2.13.10.10   Boiler Monitoring and Control

The software shall remotely monitor and control boiler operation based on

boiler operational data. The program shall monitor inputs and discontinue
boiler operation if any monitored point exceeds a predetermined value or
changes status incorrectly. The operator shall be able to add or delete
individual program input points from the list of points that will
discontinue boiler operation.

    a. Program Inputs
       (1) Flame status.
       (2) Hot water flow.
       (3) Hot water supply temperature.
       (4) Hot water return temperature.

    b. Program Outputs

       (1) Boiler enable/disable control signal.
       (2) Boiler enable/disable permission to boiler operator for
manual control.

PART 3   EXECUTION

3.1   GENERAL INSTALLATION CRITERIA

3.1.1   HVAC Control System

The HVAC control system shall be completely installed and ready for
operation. Dielectric isolation shall be provided where dissimilar metals
are used for connection and support. Penetrations through and mounting
holes in the building exterior shall be made watertight. The HVAC control
system installation shall provide clearance for control system maintenance
by maintaining access space between coils, access space to mixed-air
plenums, and other access space required to calibrate, remove, repair, or
replace control system devices. The control system installation shall not
interfere with the clearance requirements for mechanical and electrical
system maintenance.

3.1.2   Software Installation

Software shall be loaded for an operational system, including databases for
all points, operational parameters, and system, command, and application
software. The Contractor shall provide original and backup copies of
source, excluding the general purpose operating systems and utility
programs furnished by computer manufacturers and the non-job-specific
proprietary code furnished by the system manufacturer, and object modules
for software on each type of media utilized, within 30 days of formal
Government acceptance. In addition, a copy of individual floppy disks of
software for each DDC panel shall be provided.

3.1.3   Device Mounting Criteria

Devices mounted in or on piping or ductwork, on building surfaces, in
mechanical/electrical spaces, or in occupied space ceilings shall be
installed in accordance with manufacturer's recommendations and as shown.
Control devices to be installed in piping and ductwork shall be provided
with required gaskets, flanges, thermal compounds, insulation, piping,
fittings, and manual valves for shutoff, equalization, purging, and
calibration. Strap-on temperature sensing elements shall not be used
except as specified.

3.1.4   Wiring Criteria

Wiring external to control panels, including low-voltage wiring, shall be installed in metallic raceways. Wiring shall be installed without splices between control devices and DDC panels. Instrumentation grounding shall be installed as necessary to prevent ground loops, noise, and surges from adversely affecting operation of the system. Ground rods installed by the contractor shall be tested as specified in IEEE Std 142. Cables and conductor wires shall be tagged at both ends, with the identifier shown on the shop drawings. Electrical work shall be as specified in Section 16415A ELECTRICAL WORK, INTERIOR and as shown.

3.2   CONTROL SYSTEM INSTALLATION

3.2.1   Damper Actuators

Actuators shall not be mounted in the air stream. Multiple actuators operating a common damper shall be connected to a common drive shaft. Actuators shall be installed so that their action shall seal the damper to the extent required to maintain leakage at or below the specified rate and shall move the blades smoothly.

3.2.2   Local Gauges for Actuators

Pneumatic actuators shall have an accessible and visible receiver gauge installed in the tubing lines at the actuator as shown.

3.2.3   Room Instrument Mounting

Room instruments , such as wall mounted thermostats, shall be mounted 1.5 m 60 inchesabove the floor unless otherwise shown. Temperature setpoint devices shall be recess mounted.

3.2.4   Freezestats

For each 2 square meters 20 square feetof coil face area, or fraction thereof, a freezestat shall be provided to sense the temperature at the location shown. Manual reset freezestats shall be installed in approved, accessible locations where they can be reset easily. The freezestat sensing element shall be installed in a serpentine pattern.

3.2.5   Averaging Temperature Sensing Elements

Sensing elements shall have a total element minimum length equal to 3 m per square meter 1 linear foot per square footof duct cross-sectional area.

3.2.6   Foundations and Housekeeping Pads

Foundations and housekeeping pads shall be provided for the HVAC control system air compressors.

3.2.7   Indication Devices Installed in Piping Systems

Thermometers and temperature sensing elements installed in piping systems shall be installed in thermowells.

3.3   CONTROL SEQUENCES OF OPERATION

3.3.1   System Requirements

These requirements shall apply to all primary HVAC systems unless modified
herein. The sequences describe the actions of the control system for one
direction of change in the HVAC process analog variable, such as
temperature, humidity or pressure. The reverse sequence shall occur when
the direction of change is reversed.

3.3.2   HVAC Systems

Sequence of control for HVAC systems shall be as indicated on drawings.

3.4   COMMISSIONING PROCEDURES

3.4.1   Evaluations

The Contractor shall make the observations, adjustments, calibrations,
measurements, and tests of the control systems, set the time schedule, and
make any necessary control system corrections to ensure that the systems
function as described in the sequence of operation.

3.4.1.1   Item Check

Signal levels shall be recorded for the extreme positions of each
controlled device. An item-by-item check of the sequence of operation
requirements shall be performed using Steps 1 through 4 in the specified
control system commissioning procedures. Steps 1, 2, and 3 shall be
performed with the HVAC system shut down; Step 4 shall be performed after
the HVAC systems have been started. External input signals to the DDC
system (such as starter auxiliary contacts, and external systems) may be
simulated in steps 1, 2, and 3. With each operational mode signal change,
DDC system output relay contacts shall be observed to ensure that they
function.

3.4.1.2   Weather Dependent Test Procedures

Weather dependent test procedures that cannot be performed by simulation
shall be performed in the appropriate climatic season. When simulation is
used, the actual results shall be verified in the appropriate season.

3.4.1.3   Two-Point Accuracy Check

A two-point accuracy check of the calibration of each HVAC control system
sensing element and transmitter shall be performed by comparing the DDC
system readout to the actual value of the variable measured at the sensing
element and transmitter or airflow measurement station location. Digital
indicating test instruments shall be used, such as digital thermometers,
motor-driven psychrometers, and tachometers. The test instruments shall be
at least twice as accurate as the specified sensing element-to-DDC system
readout accuracy. The calibration of the test instruments shall be
traceable to National Institute Of Standards And Technology standards. The
first check point shall be with the HVAC system in the shutdown condition,
and the second check point shall be with the HVAC system in an operational
condition. Calibration checks shall verify that the sensing element-to-DDC
system readout accuracies at two points are within the specified product
accuracy tolerances. If not, the device shall be recalibrated or replaced
and the calibration check repeated.

3.4.1.4   Insertion and Immersion Temperatures

Insertion temperature and immersion temperature sensing elements and
transmitter-to-DDC system readout calibration accuracy shall be checked at
one physical location along the axis of the sensing element.

3.4.1.5   Averaging Temperature

Averaging temperature sensing element and transmitter-to-DDC system readout
calibration accuracy shall be checked every 600 mm 2 feetalong the axis of
the sensing element in the proximity of the sensing element, for a maximum
of 10 readings. These readings shall then be averaged.

3.4.2   Unit Heaters

The "OFF/AUTO" switch shall be placed in the "OFF" position.   The unit
heater fan shall not start. The "OFF/AUTO" switch shall be placed in the
"AUTO" position.   The space thermostat temperature setting shall be turned
up so that it makes contact and turns on the unit heater fan. The space
thermostat temperature setting shall be turned down, and the unit-heater
fan shall stop. The thermostats shall be set at their temperature setpoint.

3.4.3   Supply and Exhaust Fans

The "OFF/ON/AUTO" switch shall be placed in the "OFF" position. It shall
be ensured that the fan stops. The "OFF/ON/AUTO" switch shall be placed in
the "ON" position. It shall be ensured that the fan starts.   The
"OFF/ON/AUTO" switch shall be placed in the "AUTO" position. With space
thermostat temperature setting turned down, the fan shall starts, and with
space thermostat temperature setting turned up, the fan shall stops. The
thermostats shall be set at their temperature setpoints. The results of
testing of one of each type of unit shall be logged.

3.4.4   Fan-Coil-Unit

The dual-temperature hydronic system shall be set to heating. Each space
thermostat temperature setting shall be turned up so that it makes contact
and turns the fan-coil unit on. The fan-coil unit fan shall start and the
valves shall open to flow through the coils. Each space thermostat
temperature setting shall be turned down and the fan-coil unit fans shall
stop. The valves shall close to flow through the coils. The
dual-temperature hydronic system shall be switched to cooling. Each space
thermostat temperature setting shall be turned up; contact shall be broken
and the fan-coil unit fans shall stop. The valves shall close to flow
through the coil. Each space thermostat temperature setting shall be
turned down. The fan-coil unit fans shall start and the valves shall open
to flow through the coils. The thermostats shall be set at the temperature
setpoints as shown. The results of testing of one of each type of unit
shall be logged.

3.4.5   Multizone Air Handling Units

Steps for installation shall be as follows:

   a. Step 1 - System Inspection: The air handling unit shall be
       verified in its shutdown condition. The outside-air damper shall
       be closed, and the cooling-coil valve shall be closed.

b.   Step 2 - Calibration Accuracy Check with air handling unit Shutdown: Readings shall be taken with a digital thermometer at each temperature-sensing element location.   Each temperature shall be read at the DDC controller, and the thermometer and DDC system readings logged.   The calibration accuracy of the sensing element-to-DDC system readout for outside-air, return-air, mixed air, cold-deck air, hot-deck air, and space temperatures shall be checked.

c.   Step 3 - Actuator Range Adjustments: A signal shall be applied to the actuator through an operator entered value to the DDC system. The proper operation of the actuators for all dampers and valves shall be verified. The signal shall be varied from live zero of 4 ma to 20 ma, and it shall be verified that the actuators travel from zero stroke to full stroke within the signal range. It shall be verified that all sequenced and parallel-operated actuators move from zero stroke to full stroke in the proper direction, and move the connected device in the proper direction from one extreme position to the other.

d.   Step 4 - Control-System Commissioning:

(1) With the fans ready to start, the system shall be placed in the ventilation delay mode and in the occupied mode, and it shall be that supply fan start. It shall be verified that the outside-air damper is closed, and the heating and cooling-coil valves are under control, by artificially changing the hot and cold deck temperatures through operator entered values. The system shall be placed out of the ventilation delay mode through an operator entered value and it shall be verified that the outside air, return air, and relief air dampers come under control, by artificially changing the mixed air temperature..

(2) The control system shall be placed in the minimum outside air mode. It shall be verified that the outside air damper opens to minimum position.

(3) The economizer mode shall be simulated by a change in the outside air temperature and the return air temperature through operator entered values and it shall be verified that the system goes into the economizer mode. The mixed air temperature shall be artificially changed through operator entered values to slightly open the outside air damper and the second point of the two-point calibration accuracy check of sensing element-to-DDC system readout for outside air, return air, and mixed air temperatures shall be performed. The temperature setpoint shall be set as shown.

(4) The two-point calibration accuracy check of sensing element-to-DDC system readout for outside air and hot-deck temperatures shall be performed. The hot deck temperature setpoint shall be set for minus 4 degrees C [_____] degrees Fat 20-ma input and 18 degrees C [_____] degrees Fat 4-ma input. The outside air temperature shall be artificially changed through operator entered values. Three values shall be entered simulating outside air temperature changes. The values shall be selected at midrange, lower 1/3 range, and upper 1/3 range of the temperature schedule. It shall be verified that the hot-deck temperature setpoint tracks the schedule. The hot-deck temperature setpoint shall be set for

the existing outside air temperature as shown. A change shall be
simulated in the coil discharge air temperature through an operator
entered value and it shall be verified that the control valve is
modulated.

(5) The two-point calibration accuracy check of sensing
element-to-DDC system readout for the cold-deck temperature shall
be performed. The cold-deck temperature setpoint shall be set as
shown. A change shall be simulated in the coil discharge air
temperature through an operator entered value and it shall be
verified that the control valve is modulated.

(6)   The control system shall be placed in the unoccupied mode,
and it shall be verified that the air handling unit shuts down, and
the control system assumes the specified shutdown conditions. The
space temperature shall be artificially changed to below the night
setback setpoint and it shall be verified that the HVAC system
starts; the space temperature shall be artificially changed to
above the night setback setpoint, and it shall be verified that the
HVAC system stops. The night setback temperature setpoint shall be
set as shown.

(7) With the air handling unit running, a filter
differential-pressure switch input signal shall be simulated at the
device. It shall be verified that the filter alarm is initiated.
The differential pressure switch shall be set at the setpoint.

(8) With the air handling unit running, a freezestat trip input
signal shall be simulated at the device. Air handling unit
shutdown shall be observed. It shall be verified that a low
temperature alarm is initiated. The freezestat shall be set at the
setpoint. The HVAC system shall be restarted by manual restart and
it shall be verified that the alarm returns to normal.

(9) With the air handling unit running, a smoke-detector trip
input signal shall be simulated at each detector, and
control-device actions and interlock functions shall be verified.
Simulation shall be performed without false-alarming any Life
Safety systems. It shall be verified that the air handling unit
shuts down and that the smoke detector alarm is initiated. The
detectors shall be reset. The air handling unit shall be restarted
by manual restart, and it shall be verified that the alarm signal
is changed to a return-to-normal signal.

(10) The setpoint of each zone thermostat shall be raised and it
shall be verified that the zone damper closes to the cold deck and
opens to the hot deck. The thermostat of each zone shall be
calibrated and set at its setpoint as shown.

3.4.6   Heating Water Control System

  Steps for installation shall be as follows:

        a. Step 1 - System Inspection: The heating water control system
            shall be observed in its shutdown condition.

        b. Step 2 - Calibration Accuracy Check with Heating Water Control

System in Shutdown: Readings shall be taken with a digital thermometer at each temperature-sensing element location. Each temperature shall be read at the DDC controller, and the thermometer and DDC system readings logged. The calibration accuracy of the sensing element-to-DDC system readout for outside-air temperature and heating water supply temperature shall be checked.

c. Step 3 - Actuator Range Adjustments: A signal shall be applied to the actuator through an operator entered value to the DDC system. The proper operation of the actuator for the control valve shall be verified visually. The signal shall be varied from live zero of 4 ma to 20 ma, and it shall be verified that the actuator travel from zero stroke to full stroke within the signal range, and move the connected device in the proper direction from one extreme position to the other.

d. Step 4 - Control-System Commissioning:

(1) The two-point calibration sensing element-to-DDC system readout accuracy check for the outside air temperature shall be performed. Any necessary software adjustments shall be made to setpoints or parameters to achieve the outside air temperature schedule.

(2) The outside air temperature shall be simulated to be above the setpoint through an operator entered value. It shall be verified that the hot water heating pumps stop. A signal shall be applied to simulate that the outside-air temperature is below the setpoint shown. It shall be verified that the hot water heating pumps start.

(3) The two-point calibration accuracy check of the sensing element-to-DDC system readout for the system-supply temperature shall be performed. The supply temperature setpoint shall be set for the schedule as shown. Signals of 8 ma and 16 ma shall be sent to the DDC system from the outside-air temperature sensor, to verify that the supply temperature setpoint changes to the appropriate values.

3.4.7   Chilled Water Control System

Steps for installation shall be as follows:

a. Step 1 - System Inspection: The chilled water control system shall be observed in its shutdown condition.

b. Step 2 - Calibration Accuracy Check with Chilled Water Control System in Shutdown: Readings shall be taken with a digital thermometer at each temperature-sensing element location. Each temperature shall be read at the DDC controller, and the thermometer and DDC system readings logged. The calibration accuracy of the sensing element-to-DDC system readout for all chilled water supply and return, condenser water supply and return temperatures, etc. shall be checked.

c. Step 3 - Control-System Commissioning:

(1) The outside air temperature shall be simulated to be above
the setpoint through an operator entered value. It shall be
verified that chilled water pumps CHP-1 and CHP-2 start, and
chiller control system is enabled. A value shall be entered to
simulate that the outside air temperature is below the setpoint.
It shall be verified that chilled water pumps CHP-1 and CHP-2
stop, and chiller control system is dis-abled.

(2) When chiller control system is enabled. It shall be
verified that "Lead" chiller pump CP-1, condenser water pump
CWP-1, and cooling tower CT-1 fan (low-speed) start.

(3) A signal shall be applied to simulate that the return
chilled water temperature to the chillers is above the setpoint
as shown. It shall be verified that the chiller sequencing
control starts. A signal shall be applied to simulate that the
return chilled water temperature is below the setpoint as shown.
It shall be verified that the chiller sequencing control stop.

(4) The two-point calibration sensing element-to-DDC system
readout accuracy check for each condenser water and cooling tower
water temperature shall be performed. A change shall be
simulated in the cooling tower water temperature through an
operator entered value and it shall be verified that cooling
tower fan high-speed control starts.

(5) The two-point calibration accuracy check of sensing
element-to-DDC system readout for the distribution chilled water
supply and return temperature, chiller supply water temperatures,
and cooling tower water temperatures shall be performed. The
temperature setpoints shall be set as shown. A change above the
high limit setpoint shall be simulated for all these water
temperatures through an operator entered value and it shall be
verified that the high limit alarm is initiated. A change below
the low limit setpoint shall be simulated for all these water
temperatures through an operator entered value and it shall be
verified that the low limit alarm is initiated.

3.5   BALANCING, COMMISSIONING, AND TESTING

3.5.1   Coordination with HVAC System Balancing

Commissioning of the control system, except for tuning of controllers,
shall be performed prior to or simultaneous with HVAC system balancing.
The contractor shall tune the HVAC control system after all air system and
hydronic system balancing has been completed, minimum damper positions set
and a report has been issued.

3.5.2   Control System Calibration, Adjustments, and Commissioning

Control system commissioning shall be performed for each HVAC system, using
test plans and procedures previously approved by the Government. The
Contractor shall provide all personnel, equipment, instrumentation, and
supplies necessary to perform commissioning and testing of the HVAC control
system. All instrumentation and controls shall be calibrated and the
specified accuracy shall be verified using test equipment with calibration
traceable to NIST standards. Wiring shall be tested for continuity and for
ground, open, and short circuits. Mechanical control devices shall be

adjusted to operate as specified. HVAC DDC control panels shall be
pretested off-site as a functioning assembly ready for field connections,
calibration, adjustment, and commissioning of the operational HVAC control
system. Control parameters and logic (virtual) points including control
loop setpoints, gain constants, and integral constraints, shall be adjusted
before the system is placed on line. Communications requirements shall be
as indicated. Written notification of any planned commissioning or testing
of the HVAC Control systems shall be given to the Government at least 14
calendar days in advance.

3.5.3   Performance Verification Test

   The Contractor shall demonstrate compliance of the HVAC control system with
   the contract documents. Using test plans and procedures previously
   approved by the Government, the Contractor shall demonstrate all physical
   and functional requirements of the project. The performance verification
   test shall show, step-by-step, the actions and results demonstrating that
   the control systems perform in accordance with the sequences of operation.
   The performance verification test shall not be started until after receipt
   by the Contractor of written permission by the Government, based on
   Government approval of the Commissioning Report and completion of
   balancing. The tests shall not be conducted during scheduled seasonal off
   periods of base heating and cooling systems.

3.5.4   Endurance Test

   The endurance test shall be used to demonstrate the specified overall
   system reliability requirement of the completed system. The endurance test
   shall not be started until the Government notifies the Contractor in
   writing that the performance verification test is satisfactorily
   completed. The Government may terminate the testing at any time when the
   system fails to perform as specified. Upon termination of testing by the
   Government or by the Contractor, the Contractor shall commence an
   assessment period as described for Phase II. Upon successful completion of
   the endurance test, the Contractor shall deliver test reports and other
   documentation as specified to the Government prior to acceptance of the
   system.

        a.   Phase I (Testing). The test shall be conducted 24 hours per day,
   7 days per week, for 15 consecutive calendar days, including holidays, and
   the system shall operate as specified. The Contractor shall make no
   repairs during this phase of testing unless authorized by the Government in
   writing.

        b.   Phase II (Assessment). After the conclusion of Phase I, the
   Contractor shall identify failures, determine causes of failures, repair
   failures, and deliver a written report to the Government. The report shall
   explain in detail the nature of each failure, corrective action taken,
   results of tests performed, and shall recommend the point at which testing
   should be resumed. After delivering the written report, the Contractor
   shall convene a test review meeting at the jobsite to present the results
   and recommendations to the Government. As a part of this test review
   meeting, the Contractor shall demonstrate that all failures have been
   corrected by performing appropriate portions of the performance
   verification test. Based on the Contractor's report and test review
   meeting, the Government may require that the Phase I test be totally or
   partially rerun. After the conclusion of any retesting which the
   Government may require, the Phase II assessment shall be repeated as if

Phase I had just been completed.

3.5.5   Posted and Panel Instructions

Posted and Panel Instructions, showing the final installed conditions, shall be provided for each system. The posted instructions shall consist of laminated half-size drawings and shall include the control system schematic, equipment schedule, sequence of operation, wiring diagram, communication network diagram, and valve and damper schedules. The posted instructions shall be permanently affixed, by mechanical means, to a wall near the control panel. Panel instructions shall consist of laminated letter-size sheets and shall include a Routine Maintenance Checklist and as-built configuration check sheets. Panel instructions and one copy of the Operation and Maintenance Manuals, previously described herein, shall be placed inside each control panel or permanently affixed, by mechanical means, to a wall near the panel.

3.6   TRAINING

3.6.1   Training Course Requirements

A training course shall be conducted for 6 operating staff members designated by the Contracting Officer in the maintenance and operation of the system, including specified hardware and software. The training period, for a total of 32 hours of normal working time, shall be conducted within 30 days after successful completion of the performance verification test. The training course shall be conducted at the project site. Audiovisual equipment and 6 sets of all other training materials and supplies shall be provided. A training day is defined as 8 hours of classroom instruction, including two 15 minute breaks and excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility.

3.6.2   Training Course Content

For guidance in planning the required instruction, the Contractor shall assume that attendees will have a high school education or equivalent, and are familiar with HVAC systems. The training course shall cover all of the material contained in the Operating and Maintenance Instructions, the layout and location of each HVAC control panel, the layout of one of each type of unitary equipment and the locations of each, the location of each control device external to the panels, preventive maintenance, troubleshooting, diagnostics, calibration, adjustment, commissioning, tuning, and repair procedures. Typical systems and similar systems may be treated as a group, with instruction on the physical layout of one such system. The results of the performance verification test and the calibration, adjustment and commissioning report shall be presented as benchmarks of HVAC control system performance by which to measure operation and maintenance effectiveness.

 -- End of Section --